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Non-operative Management of Penetrating Abdominal Injuries: An Update on Patient Selection

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Abstract
Purpose To review the current literature, discuss the different mechanisms of penetrating trauma, and to understand the value of diagnostic modalities when deciding which patients may be safely observed non-operatively.
Recent Findings Recent findings have shown the success of selective non-operative management in all forms of penetrating trauma, with emphasis on understanding the mechanism, the importance of the abdominal exam, and a well-organized infrastructure conducive to accurate monitoring and serial abdominal exams.
Summary Non-operative management for penetrating abdominal wounds has established itself as a viable option in the stable patient. Despite increasing evidence of the safety and overall benefit, there are still controversies and difficulties when deciding which patient is suitable for non-operative management. As experience with non-operative management continues to grow, it is vital that an institution develops its own protocols based on the current evidence, their patient population, and resources available.

Keywords Penetrating abdominal trauma · Non-operative management · Penetrating trauma · Stab · Gunshot · Abdomen

Introduction

As occurred with blunt abdominal trauma, there has been a movement towards selective non-operative management (SNOM) of stable patients after penetrating abdominal wounds. The latest research demonstrates that this approach in a select group of patients does not increase mortality. Rather, it reduces morbidity and exponentially decreases healthcare costs. Nevertheless, in order for SNOM to succeed, a meticulous approach must be taken when evaluating, diagnosing, and monitoring these patients.

There are a variety of traumatic pathologies that are defined as penetrating. Each mechanism is unique, requiring different approaches and considerations to determine if the patient is a non-operative candidate. Penetrating injuries may include bullet wounds, stab wounds, blast injury, and impalement injuries. Given the heterogeneity of these events, a thorough understanding of the physiokinetics of penetrating injury is required, along with a precise initial evaluation of the patient.

If a patient is deemed unstable or has signs of hollow viscus injury (i.e., peritonitis, hematemesis/blood in the nasogastric tube, blood in the rectum, or bowel content extruding from the wound), SNOM is no longer an option and immediate intervention is necessary. These patients require a definitive or damage control procedure. As SNOM gains wider acceptance, other clinical findings remain disputed when deciding whether the patient is a good SNOM candidate. These 'gray zone' signs include evisceration, free air on X-ray, altered mental status, positive local wound exploration (LWE), or the transient response to resuscitation. The decision to proceed with a non-operative approach is highly dependent upon the treating center's ability to observe the patient (including

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the manpower to accurately conduct serial abdominal exams), the surgeon's experience, and available imaging. Here we will review how best to select patients for SNOM regarding low velocity injuries (stab/impalements) versus medium/high velocity injuries (gunshot wounds), and the current evidence regarding SNOM.

The Evolution of SNOM in Penetrating Abdominal Injuries

Prior to the 19th century, penetrating trauma to the abdomen was often deemed non-operative because it was almost certain to be fatal [1]. Towards the end of the 19th century, the dogma that "nothing is of avail" except an early laparotomy began to gain momentum for the unstable and stable patients in effort to save lives [2]. Standards of care drastically evolved between World War I and World War II. During this time surgeons began to understand the urgency required to conduct definitive surgical care [1]. In all patients with a penetrating abdominal wound, the practice of immediate laparotomy continued until the 1960s when surgeons took note of the high percentage of negative laparotomies. They often found 50% of patients with penetrating abdominal wounds actually had the peritoneum intact. However, even when the peritoneum was violated 60% of the patients had a non-therapeutic laparotomy [3]. In addition, reports began to appear in the surgical literature documenting the high morbidity related to negative laparotomies [4], and the economic loss caused by unnecessary surgery [5].

The successful SNOM of stable penetrating trauma patients (as a treatment decision and goal) has been present in the literature for decades [6]. Nevertheless, even into the late 20th century, a prominent number of surgeons held onto the notion that a laparotomy is the "quickest and easiest way to exclude injury" while having minimal morbidity [7••]. In the last decade, research has increasingly validated SNOM, with respect to both stab and projectile penetrating abdominal wounds, as a safe and favorable option in certain environments and scenarios [8].

The Negative Laparotomy: Epidemiology and Consequence

In order to accurately and safely select the patients for non-operative management, one must understand the epidemiology and consequences of an unnecessary surgery (considered either a negative or non-therapeutic surgery). Low volume penetrating trauma centers [9, 10], and level II centers [11], have shown success in SNOM with results comparable to their level I counterparts. Nevertheless, in all levels of trauma centers, there remains a significant number of negative laparotomies despite improvements in the assessment and treatment of the trauma patients over the past decades.

There is a wide range of variation between the reported incidences of unnecessary surgeries after penetrating trauma among various hospitals. This discrepancy is thought to be dependent on the mechanism of penetrating injury (gunshot versus stab wound), and is influenced to a lesser degree by geography, economics, trauma volume/experience, location on the abdomen of the injury, or the year the data were obtained. There have been a consistently higher number of unnecessary surgeries for stab wounds when compared to other mechanisms of penetrating trauma. For example, two recent studies from high-volume centers in South Africa and the United States reported unnecessary laparotomies for gunshot wounds at 3.5% [12••] and for stab wounds at 56% [13], while recent studies from lower volume centers in the Netherlands and Canada showed a comparable difference of 7.6% unnecessary surgeries (where 56% of the injured were from stab wounds and 44% from gunshot wounds) [14] to 43% unnecessary surgeries where the majority of injuries were from stab wounds [15].

With regard to the year the study was conducted, over the last five decades there is a lack of significant improvement in decreasing the percentage of unnecessary surgery despite more experience with penetrating trauma, research, and advancements in technology. A report from the United States in 1976 showed an unnecessary laparotomy rate of 25% in stab wounds and 8% with GSW [16]. In 1987, a study from South African involving abdominal stab wounds showed a 4% unnecessary laparotomy rate [17]. A 1995 study at a center in the United States reported 12% and 23% for negative laparotomies after GSW and stab wounds, respectively [18]. More recently, a 2017 study from South Africa reported an incidence of 10% unnecessary laparotomies in all penetrating abdominal injury over the course of a year [19].

The unique conditions of war time surgery must also be mentioned. Compared to areas without military conflict, and even though there are more gunshot-wound victims, this environment lends itself to a higher rate of unnecessary laparotomy thought to be due to the inherent difficulty and dangers when triaging patients to SNOM. A recent series from the Iraq and Afghanistan wars reported having a 32% rate of non-therapeutic laparotomies [20]. During the same war in Iraq, a mobile field hospital published a rate of 64% negative laparotomies [21]. The challenges to manage SNOM in this austere environment include a rapid/mass influx of casualties, limited resources/diagnostic ability, higher velocity weapons, higher percentage of blast injury, and rapid transport of patients to other centers. In this

setting, serial abdominal exams become erratic and variable. There is also a higher consequence of missing an injury because of outside factors determining the ability (or inability) to operate in a timely fashion, and not necessarily based on the clinical status of the patient.

Most surgical centers today support the appropriate use of SNOM in an effort to avoid unnecessary complications and poor allocation of resources, and decrease the length of hospital stay. An avoidable surgery presents a clear burden, not only to the patient and the cost to the hospital, but also the negative impact on the community by decreasing productive school and work days [22]. Differences have also been shown in the length of hospitalization, morbidity, and cost between non-therapeutic surgeries (those identifying injury without the need for intervention or drain placement) and a completely negative laparotomy [23]. For these reasons, research continues to investigate the limits of SNOM, including evaluation of its safety when there are equivocal clinical and diagnostic findings [24].

During the initial hospitalization, short-term complications include atelectasis, pneumonia, prolonged ileus, dehiscence, surgical wound infection, early small bowel obstruction, intra-abdominal abscess, venous thromboembolism, and urinary tract infections [23]. Short-term complications in civilian studies vary in prevalence. High-volume level I centers in the U.S. have documented that a negative laparotomy can lead to a short-term complication rate of 14–41% [23, 25], while recent military studies reported a rate of 1.7% for early intra-abdominal complications, which included ileus, intra-abdominal abscess, and post-operative hemorrhage [20]. Associated injuries (non-abdominal) corresponded with a higher overall complication rate and a longer hospitalization, when compared to patients undergoing a negative laparotomy without associated injuries [7••]. Average length of hospitalization reported after an unnecessary surgery ranges from 4.7 to 11 days [23, 26]. This is affected by short-term complications and/or associated non-abdominal injuries. Most of the patients after successful SNOM are discharged between 24 and 48 h after presentation to the hospital [24].

The majority of long-term complications after a laparotomy for trauma are either a small bowel obstruction (SBO) or incisional hernia (IH). When reporting the long-term complications, most of the retrospective studies do not differentiate between penetrating or a blunt trauma for the initial event. Clinically relevant SBO and IH (after fascia was primarily closed during the initial surgery) have been found to be 6.6% and 10.5% [27].

Although the mortality rate for a negative laparotomy is low, it is not negligible. Early reports showed a mortality from 0.2 to 6% [26, 28]. Nevertheless, it is difficult to accurately report the cause of death after a penetrating trauma and distinguish if the complications were a result of the negative laparotomy. The published cases of death have been related to aspiration, intoxication/drug overdose, or unknown/undiagnosed associated injuries.

SNOM Regarding Different Mechanisms of Penetrating Trauma

Stab wounds have a wide spectrum of velocities, forces, and mechanics that may each affect the extent of injury. Knowing these details will assist the surgeon in determining if it is safe to proceed with SNOM or if the patient will benefit from surgical exploration. A ‘stab’ wound can be from a butter knife, a butcher knife, or a machete, all with variable level of sharpness, potential depths of penetration, and ability to damage tissue [29]. The energy from the stab wound may also be inconsistent, with differences in force between a self-inflicted stab [30], an overhand, or underhand thrust from a strong or weak attacker. Multiple studies have shown a low percentage of actual peritoneal penetration after a stab wound, and even less with significant visceral injury needing repair [31]. Without the need for immediate surgery, many of the patients with stab wounds to the abdominal wall (anterior abdomen, flanks, back) do not need an operation and are successfully managed by SNOM when following current guidelines or a local institutional specific protocol [32, 33•].

The kinematics of gunshot wounds (GSW) causes a unique and irregular pattern of tissue injury. Determinants such as high or low velocity, partial or full metal jackets, trajectories/ricochet, cavitation, and tumble, all influence the injury and morbidity of the wound [34•]. For GSW, SNOM has been utilized for decades yet remains controversial [35, 36••]. The patients without clear indications for immediate surgery may be successfully triaged into non-operative management in the hands of experienced healthcare workers, with the ability to monitor and obtain reliable serial abdominal exams. Early studies from South Africa demonstrated that one-third to one-fourth of all gunshot wounds to the abdomen may be successfully managed non-operatively (70% of those to the back/posterior abdomen), with a failure rate between 5 and 14.8% [12••, 37].

Shotguns create a low velocity projectile with a unique kinematics. The extent of damage is most influenced by the distance from the target and the time the pellets have to fan out and either cause individual damage or extensive collective damage. The injurious range is approximately 50–80 m. The same GSW management principles and indication for SNOM also include shotguns, but their wide spectrum of damage potential must be understood upon receiving the patient in the trauma bay [38].

Blast injury has a distinct effect on the body's tissues, incorporating both kinematic characteristics of blunt and penetrating injuries, along with its own damaging 'blast' effect due to overpressure and underpressure wave forms [39]. The variation and randomness of blast injury makes trajectories more difficult to establish, with a large number of different size projectiles creating various size entrance wounds. The smallest of skin wounds may be the result of a high velocity object causing significant internal damage, especially with the reports of glass, nails, and other random sharp objects used in 'home' built bombs [40•]. Even with the smallest of visible skin wounds, all patients exposed to a blast must be assumed to have a penetrating injury. An Israeli report showed even the blast effect, (without signs of penetration), may cause injury and delayed perforation to the small bowel by damaging the mucosa, creating a bowel wall hematoma, and eventually necrosis and perforation [41]. In their experience, peritonitis presented within 48 h, therefore they recommended that all patients exposed to a blast, even without external injuries to the torso, need to be monitored for at least 48 h. In an environment where blasts are common, such as war zones, recent studies for the American Forces in the Middle East and Afghanistan have shown that the majority of patients who failed SNOM in a war zone environment had blast injuries [20]. This may be due to the previously mentioned trauma system of war zones and the distinct pathophysiology of blast injury.

Recommendations for the treatment of abdominal impalement injury derive from case reports and expert opinions [42]. There are no reports, or rational, for SNOM in impalement injuries presenting to the emergency department/trauma bay. All impaled objects need to be removed in the operating room in a controlled and prepared environment, along with an aggressive washout of a highly contaminated wound. Patients who arrive to the hospital with no current object impaled, with the history of having been impaled, may be considered for SNOM as any stab wound patients would be. But there should be a lower threshold for debridement and washout of the wound as needed.

The Initial Assessment, Physical Exam, and Imaging

Even in today's technologically driven world, the importance of the initial physical exam cannot be over emphasized. Throughout the history of non-operative management for penetrating abdominal wounds, the abdominal exam continues to be the most clinically relevant factor when deciding a treatment plan.

Serial abdominal exams after abdominal penetrating injury, in the stable, reliable patient, w/o spinal cord injury, have a 98% sensitivity [12••]. One large multi-center study emphasized the importance of the physical exam by demonstrating a 45% non-therapeutic laparotomy incidence if patients were taken to the OR based solely on positive imaging studies [43]. An institution-specific protocol should be developed which incorporates evidence-based data together with the institution's own abilities and limitations. Figure 1 shows a practical and generalized algorithm for the management of penetrating trauma patients.

The abdomen is a broad term—including the anterior abdominal wall, flanks, thoracoabdominal region, and back. Due to anatomical differences, each area has specific evaluation needs which must be understood before being able to safely manage a patient non-operatively. With injury to the thoracoabdominal region (nipple line to costal margins), epigastrium (costal margins to umbilicus), high flank, or upper back, a thoracic or cardiac injury must be ruled out. Pneumothorax, hemothorax, or cardiac injury may all be reliably ruled out by a chest X-ray (preferably in the upright position) or pleura ultrasound (extended FAST), and a pericardial ultrasound [33•, 44, 45]. Thoracoabdominal gunshot wounds and SNOM brings up further questions regarding the diaphragm, and the anatomical differences between the right and left upper quadrants of the abdomen. Multiple reports have advocated a conservative non-operative approach to right-sided thoracoabdominal injury after CT scan has identified the trajectory of the bullet [46]. In our experience, we support SNOM when appropriate for right-sided thoracoabdominal injury, but we are more aggressive with thoracoscopy within 24–48 h from admission in order to rule out (or identifying and repair) diaphragmatic injury and potentially prevent a biliary pleural fistula [47]. For left-sided thoracoabdominal injuries, the SNOM is also still relevant and recommended, but all patients after the first 24 h and with low suspicion for intra-abdominal injuries should undergo laparoscopy to rule out/repair diaphragmatic injuries [48••].

The flank—between the posterior and anterior axillary lines, above the iliac crest, and below the costal margin—has a lower sensitivity to physical exam, and therefore requires CT imaging to rule out clinically significant injury to the retroperitoneum along with intraperitoneal viscera before SNOM may be considered. The use of triple contrast CT scans has a reported high sensitivity and specificity but the value added of the rectal and oral contrast does not appear to have a major advantage [49]. The downside of triple contrast CT is a minimum 90-min delay until the PO contrast has adequately reached the distal small bowel. Current penetrating trauma guidelines continue to use traditional trauma CT protocols (arterial phase of the chest with a delayed phase of the abdomen) with flank trauma [33•, 50]. Delayed images are performed if the CT scan

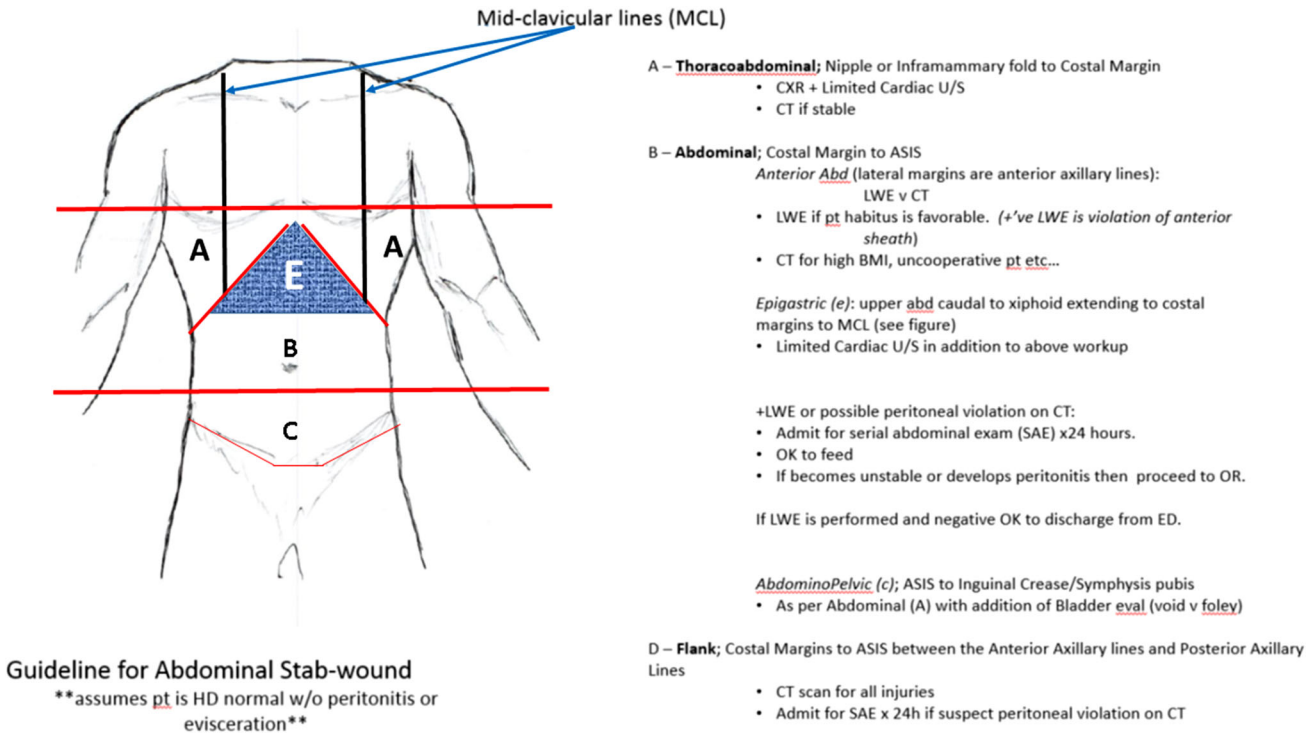

Fig. 1 Guideline of Dr. deMoya and Milia from Medical College of Wisconsin

demonstrates a renal laceration. This is done to understand if there is a urine leak or not. Research examining penetrating injuries to the back usually combine these with flank injuries. Older studies gave conflicting recommendations. Some reaffirmed the utility of CT, and suggest admitting for observation (instead of discharge from the emergency department), because of the higher risk of missed injuries due to the difficulty of evaluating the retroperitoneum on physical exam [51]. Others showed a high sensitivity and specificity of serial physical exams over a 24-h period of time when immediate surgery is not required [52].

The pelvis is its own compartment, distinct from the abdomen, with a high density of viscera and vasculature in a small cavity. Pelvic penetrating injuries have also been successfully managed with non-operative treatment. In these cases, a CT is advised, along with the important investigation of hematuria or blood per rectum, to appropriately manage non-operatively and determine if there is a need for further imaging or diagnostic studies [53].

Not all patients admitted for SNOM require additional imaging or diagnostic tests. Yet certain imaging modalities, especially CT scan, help in successful selection of the appropriate patient for non-operative management. The CT scan has supplanted many of the previously highly used diagnostics such as ultrasound, diagnostic peritoneal lavage, endoscopy, nasogastric tubes, and X-ray. By being able to image and evaluate all the potentially injured compartments (thorax, peritoneum, retroperitoneum, and pelvis), the CT scan has become a standard part of the initial trauma evaluation [54]. Despite its utility, there are other diagnostic methods that are still relevant in certain patients.

The benefit of a CT scan for the SNOM of a patient has limitations and is only auxiliary to a thorough physical exam and accurate serial abdominal exams. With certain mechanisms of penetrating abdominal trauma, a negative CT scan may allow for a safe discharge from the emergency department especially if there is a identifiable completely extra-peritoneal trajectory. Other reports have also safely discharged patients from the emergency department after a CT scan was positive for intraperitoneal penetrance but did not identify organ damage [33•, 55]. A recent meta-analysis of stable patients with stab wounds to the anterior abdominal wall concluded that 8.7% of patients with a negative CT scan required a therapeutic laparotomy, in which half of the injuries were related to the small bowel [56•]. For a gunshot wounds, a CT is sensitive in showing trajectory, but cannot accurately show peritoneal violation or intraperitoneal injury, especially with small bullet fragmentations and the cavitation effect [57], therefore suggesting an observation period before discharging GSW patients [24]. There are certain centers with protocols that contain a mandatory CT after a GSW to the abdomen [37], compared to other centers that 'selectively scan' their GSW victims. This highly experienced group from South Africa which selectively scans these patients

stresses that the primary reason for successful SNOM is based on the initial assessment of the clinical picture and the physical exam. It advocates the use of 'selective CT scans' rather than routinely. Their protocol selects CT scans for patients with either RUQ/right thoracoabdominal trajectory (in order to exclude liver injury), macro hematuria, and/or concerns from the attending surgeon [12••, 58]. They found in the patients undergoing CT scan after penetrating gunshot wound(s) to the abdomen that 95% of liver injuries and 91% of kidney injuries could be successfully treated with conservative management. In all forms of penetrating injury, a CT scan has the advantage of evaluating potential vascular injury, retroperitoneal injury, or violation of the chest compartment. Although acquiring such data might not change the SNOM decision or outcome, it facilitates additional knowledge of the overall injury burden in the patient, which can in turn aid in decisions on further treatment if the patient does not respond to conservative management or preventive measures (such as embolization).

Besides the traditional FAST exams, abdominal wall ultrasound (AWU) has been described as a method for determining a posterior fascia breach when LWE may be difficult or unobtainable after an abdominal stab wound. Compared to LWE, one study found AWU to be as specific, with a non-significant slight decrease in sensitivity [59]. Whereas AWU may be less relevant with GSW, it may have a useful application in mass casualty events with patients potentially suffering from multiple penetrating/blast injuries, when there is a strained amount of time allocated for each patient, and the CT scans is above capacity.

The FAST exam, despite having a lower sensitivity in detecting hemoperitoneum in penetrating trauma when compared to blunt trauma [60], is still widely used during the initial evaluation in penetrating trauma with uncertain benefits. For thoracoabdominal trajectory, there is a clear indication to rule out hemo/pneumothorax and hemopericardium [61]. But for anterior abdominal wall penetrating wounds, the sensitivity has remained low [62]. Currently a positive FAST for hemoperitoneum in a hemodynamically unstable patient after penetrating abdominal trauma is a clear indication for emergent laparotomy. This positive result allows the surgeon to assume that the abdominal cavity is the source of his instability. In the stable patient, a positive FAST (of the abdominal components) does not necessitate the need for surgery, and this patient will require further imaging or at least admission and observation. Therefore, in this stable patient the FAST exam is not of practical use. One example is a positive FAST of a stable patient because of non-clinically significant solid organ injury that may be successfully monitored non-operatively [54].

Diagnostic peritoneal lavage (DPL) has cycled from being a standard practice in both penetrating and blunt abdominal trauma [63, 64], to being a seldom used technique in today's trauma bay. But in select cases there are justifications for its use. For example, in the resource poor environment it may be beneficial when other diagnostic modalities are not available [33•]. Also, DPL remains in the algorithm for the stable patient with suspected thoracoabdominal injury and potential diaphragmatic injury, who have had a negative chest x-ray and negative FAST. A DPL with a threshold of less than 5000/mm^3 RBC avoided surgery by ruling out diaphragmatic injury, and allowed for safe discharge (or monitor) of these patients [61]. Certain aspirate characteristics have been validated and are considered sensitive, yet less specific, for intraperitoneal trauma needing a laparotomy after penetrating abdominal wounds. Greater than 100,000 red blood cells (RBCs)/mm^3, 500 white blood cells (WBCs)/mm^3, or elevated amylase or alkaline phosphatase or bilirubin in the lavage effluent are all considered positive [43]. Other reports consider these results to be timing dependent, causing a significant number of false-positive results and subsequent non-therapeutic surgeries [61].

The 'Gray Zone' for Safe SNOM

The principles of those needing immediate laparotomy, and who are not SNOM candidates, remain universally clear with little room for debate (Table 1). Further discussion is needed for certain 'gray zone' signs and symptoms that remain controversial for the safety of SNOM. For example, free air on abdominal imaging (either upright chest X-ray or CT) is a clear sign of peritoneal violation, but as reported recently is not a hard sign for automatic surgical exploration [33•]. These patients, based on their overall clinical picture, have been successfully managed non-operatively. Nevertheless, a lower threshold to take these patients to the operating room is recommended after blast or gunshot injuries when compared to stab wound victims [12••], especially when other concerning (or 'gray zone') signs or symptoms are present [40•].

Patients with evisceration, also once considered a definite indication for exploratory laparotomy, have been found to be safely triaged into SNOM protocol if no other indications of surgery exist. Most data agree that eviscerated omentum is safe to reduce at bedside, by closing the wound, and monitoring the patient non-operatively [65, 66]. Some trauma centers have also had successful non-operative management in patients with intact organ eviscerating [17], while other centers routinely operate on those with organ evisceration after finding that 94% of those laparotomies were therapeutic [66]. Despite evidence

Table 1 The 'hard signs' and 'gray zones' of Surgery and SNOM

Hard signs for surgery	'Gray zone' for SNOM
Peritonitis	Free air intraperitoneal air on imaging
Blood per rectum	Omental/organ evisceration
Hematemesis/blood in NG	Positive LWE
Enteric/colonic matter in wound	+ CT scan (free fluid/peritoneal infiltration/solid visceral injury)
Organ evisceration	Blast mechanism
Impalement	Altered mental status/intubated
	Spinal Cord injury and/or traumatic neurological defect
	Initially unstable then responds to fluid/resuscitation
	Positive DPL

towards SNOM for patients with eviscerated omentum, the latest algorithm by the Western Trauma Association for abdominal stab wounds still considers evisceration as needing immediate surgery [33•].

As is common with trauma patients, an altered mental status (intoxication or head injury) will decrease, if not prevent, the ability for an accurate abdominal exams and serial re-assessments. Nevertheless, SNOM has been proven safe when an initial exam is able to be obtained, and the intoxication presumably will dissipate within the following hours [67]. Problems arise when the patient has suffered significant head trauma, or is intubated, and then the physical exam becomes significantly less informative. In the unresponsive patient, the dogma that there are 'intra-abdominal injuries until proven elsewise' [37] must either be followed, or proven unlikely by the physical exam, imaging, and/or adjuvant diagnostic modalities.

Specific for stab wounds to the anterior abdomen, LWE is a valuable tool in determining violation of the fascia. LWE has a high negative predictive value when the anterior fascia has not been violated [43], therefore allowing these patients to be safely discharge from the emergency department when there are no other needs for hospitalization. However, there are limitations to LWE, such as a decreased sensitivity in an obese patient, a non-cooperative patient, or a stab wound with an oblique trajectory [68]. There is also controversy with a positive LWE in an otherwise stable patient without peritonitis. When there are no other indications, surgery is no longer deemed absolutely necessary in this group of patients. Recent protocols recommend that a positive LWE be admitted for serial abdominal exams only [33•], while others advocate the use of a CT scan or diagnostic peritoneal lavage (DPL) [69] in order to decide if the patient needs surgery regardless of the clinical picture [70, 71]. There is also debate on what is an adequate LWE. It is not universally determined if violation of just the anterior fascia is positive or if there needs to be visualization of the posterior fascia/peritoneum, to determine if the LWE was positive or negative [61].

A CT scan is positive in penetrating trauma if there is a clear trajectory through the peritoneum/retroperitoneum, solid organ injury, free air in the peritoneum or retroperitoneum, or above physiological levels of fluid in the peritoneal or retroperitoneal cavities. In the patient with positive findings on the CT scan, there is still controversy on whether surgery is mandatory. Even in patients without peritonitis, recent studies advocate surgical exploration if the trajectory, together with fluid around the bowel, is suspicious of hollow visceral injury [12••]. However, other centers have shown that SNOM may be safe even with excess fluid in the peritoneal cavity, (that is not attributed to solid organ damage), if the patient is reliable, clinically stable, and without peritonitis [12••].

SNOM has also been successfully accomplished in patient who arrived to the trauma bay hemodynamically unstable, responded to the initial resuscitation, and maintained stability for the remainder of the time in the trauma bay and during hospitalization [72]. Although certain centers safely accomplish non-operative management, this requires the most experienced of trauma teams with the highest level of ability to monitor these patients during the observation period.

As experience and research continues to grow, more evidence-based algorithms will help safely guide the SNOM of these patients, and minimize the possibility of a missed injury. Nevertheless, even with progress there will always be reports of missed injuries and/or complications. Yet recent studies have shown that even when a patient fails SNOM and worsens clinically, a delayed operation does not increase the morbidity or mortality when compared to those initially taken to emergent surgery from the trauma bay [43, 73, 74]. Such conclusions negate the mindset that a delayed surgical intervention is associated with a worse outcome, morbidity, or mortality.

Conclusion

SNOM is safe and possible in all forms of penetrating abdominal trauma. Most important factors in determining the success of SNOM are the initial clinical evaluation, abdominal exam, and determining that the patient does not need immediate surgery. Once the patient has been triaged to SNOM, and depending on the penetrating mechanism, the treating surgeon may use adjuvant imaging and/or diagnostic procedures to strengthen the positive outcome of SNOM. Missing an injury has less of a clinical significance and consequence than inadequate observation and serial abdominal exams of the patient.

Compliance with Ethical Guidelines

Conflict of interest Marc de Moya and Adam Lee Goldstein declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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